3. Properties of Waves, including Light & Sound

YOUR NOTES
⬇

CONTENTS

3.1 GENERAL WAVE PROPERTIES

3.1.1 WAVES

Waves: Basics

- Waves transfer energy between points, without transferring matter:
  - When a wave travels between two points, no matter actually travels with it: The points on the wave simply vibrate back and forth about fixed positions
- The **wavelength** of a wave is the distance from a point on one wave to the same point on the next wave. Usually this is measured from the top of one wave to the top of the next wave Wavelength is usually measured in **metres** (a distance)
- The **amplitude** of a wave is its height, measured from the middle of the wave to its top (or from the middle to its bottom)

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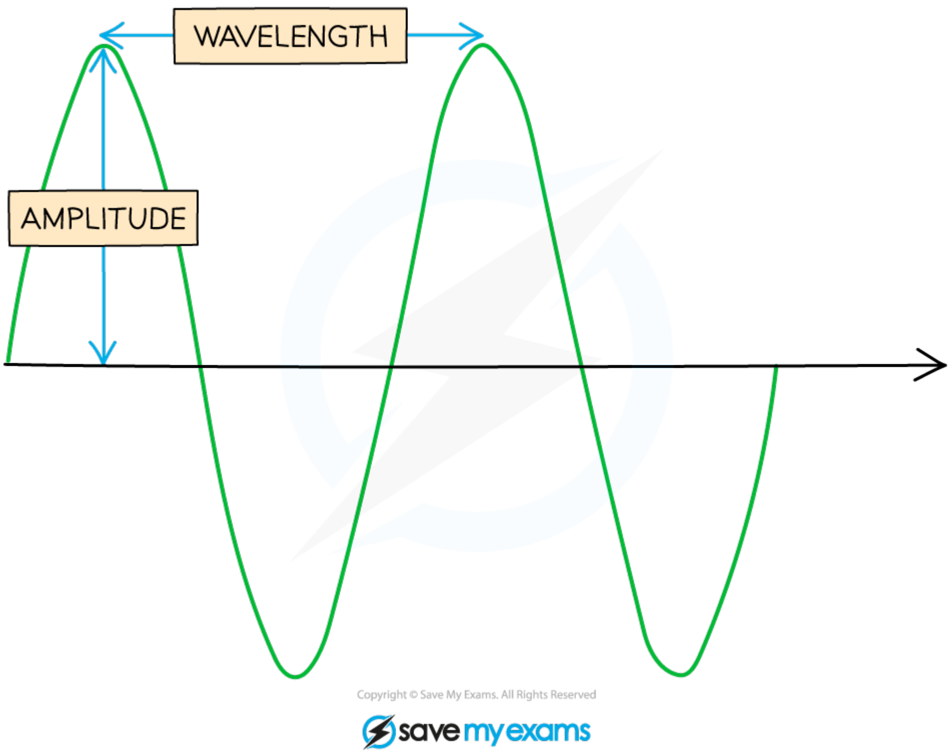

Diagram showing the amplitude and wavelength of a transverse wave

- **Wavefronts** are a useful way of picturing waves from above: each wavefront is used to represent a single wave

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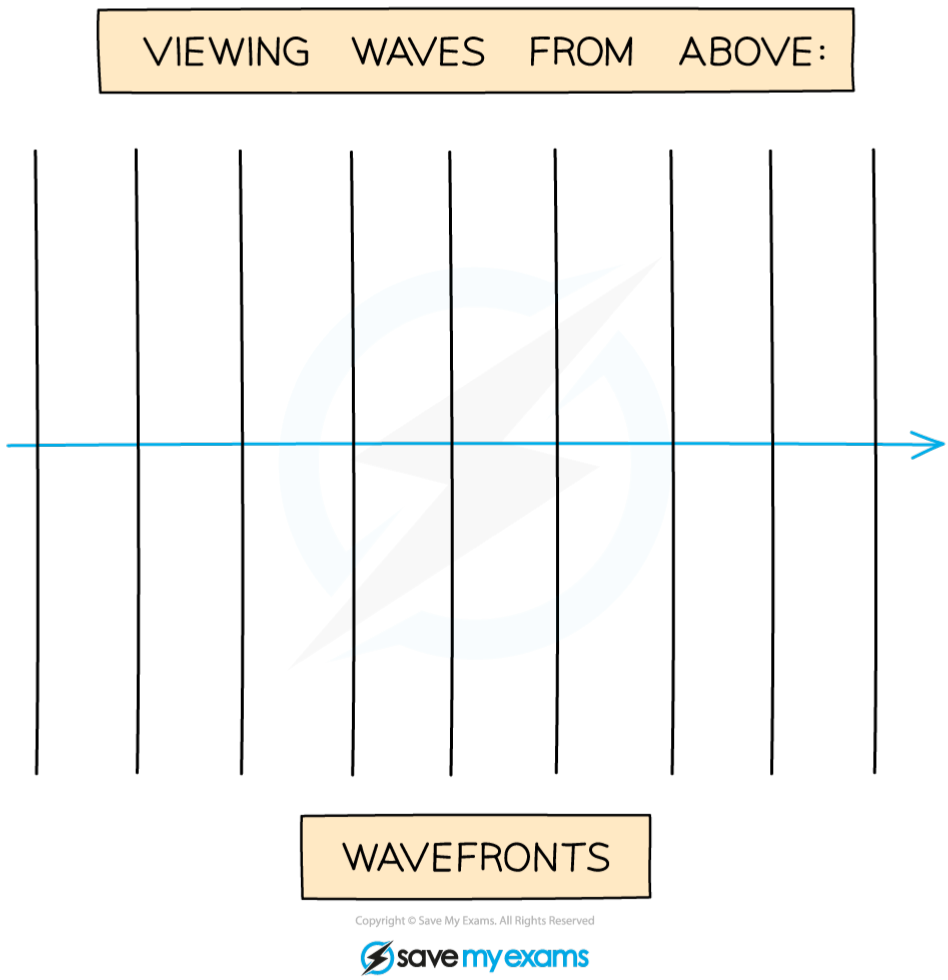

Diagram showing a wave drawn as a series of wavefronts

- The **frequency** of a wave is the number of waves passing a point (or being created or received) every second – it is helpful to think of it as being the **waves per second**
- The units of frequency are **hertz (Hz)**

Exam Tip

When labelling wavelength on a diagram, make sure that your arrows go from the **very top** of a wave to the very top of the next one: if your arrow is too short you will lose marks.

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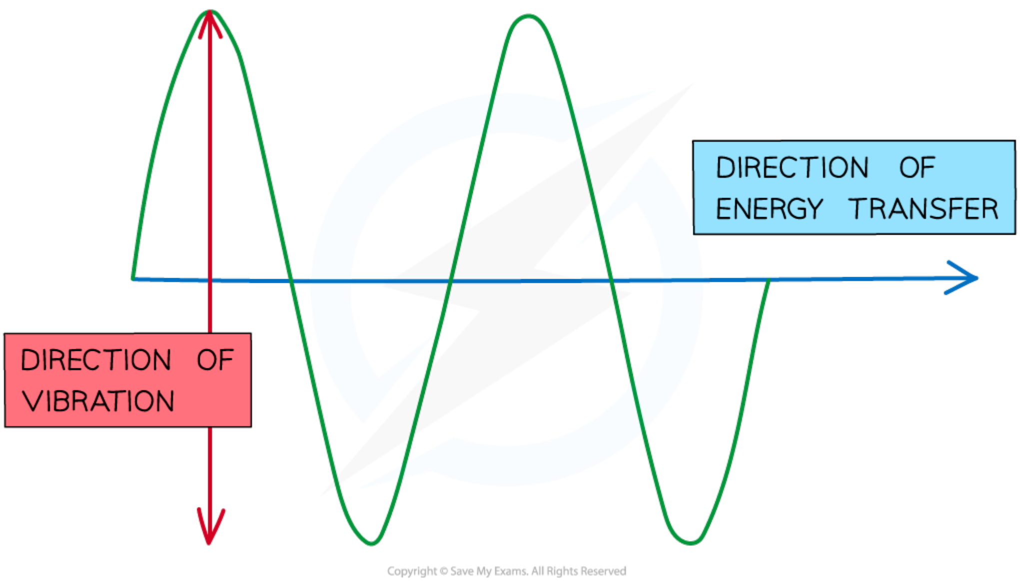
Longitudinal & Transverse Waves

- Waves can exist as one of two main types:
  - Transverse
  - Longitudinal

Transverse Waves

- For a transverse wave, the points along the wave vibrate at 90 degrees to the direction in which the wave is moving (the direction of energy transfer)



With a transverse wave, the vibrations are at 90 degrees to the direction of energy transfer

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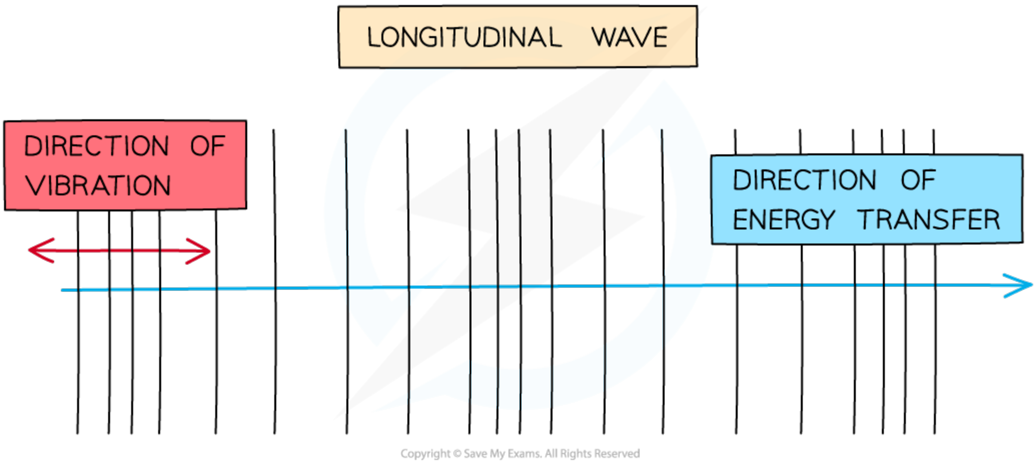
Longitudinal Waves

- For a longitudinal wave, the points along the wave vibrate in the same direction that the wave is moving in



With a longitudinal wave, the vibrations are parallel to the direction of energy transfer

Exam Tip

If asked to describe the difference between transverse and longitudinal waves, sketch the above diagrams. A good, clearly labelled diagram can earn you full marks.

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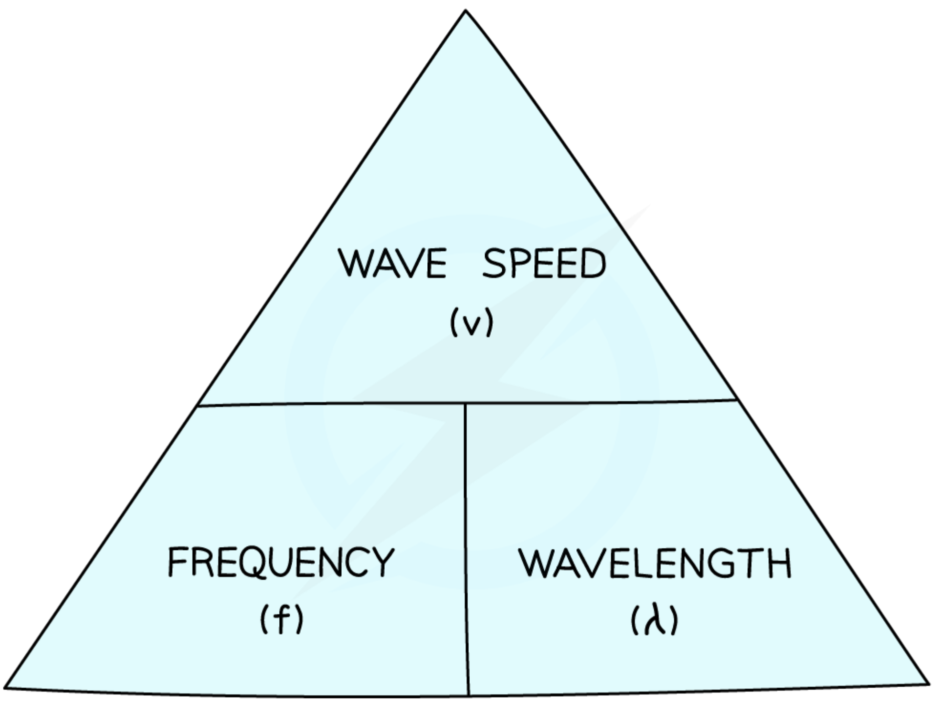
The Wave Equation

- The speed of a wave (*v*) is related to the frequency (*f*) and wavelength (*λ*) by the equation:

$$\text{WAVE SPEED} = \text{FREQUENCY} \times \text{WAVELENGTH}$$

$$v = f \times \lambda$$

- You can rearrange this equation with the help of the formula triangle:



Use the formula triangle to help you rearrange the equation

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YOUR NOTES

Exam Tip

When stating equations make sure you use the right letters:

Eg. λ for wavelength, not *L* or *W*.

If you can't remember the correct letters, then just state the word equations.

Be careful with units: wavelength is usually measured in metres and speed in m/s, but if the wavelength is given in cm you might have to give the speed in cm/s.

Likewise, watch out for frequency given in kHz: 1 kHz = 1000 Hz

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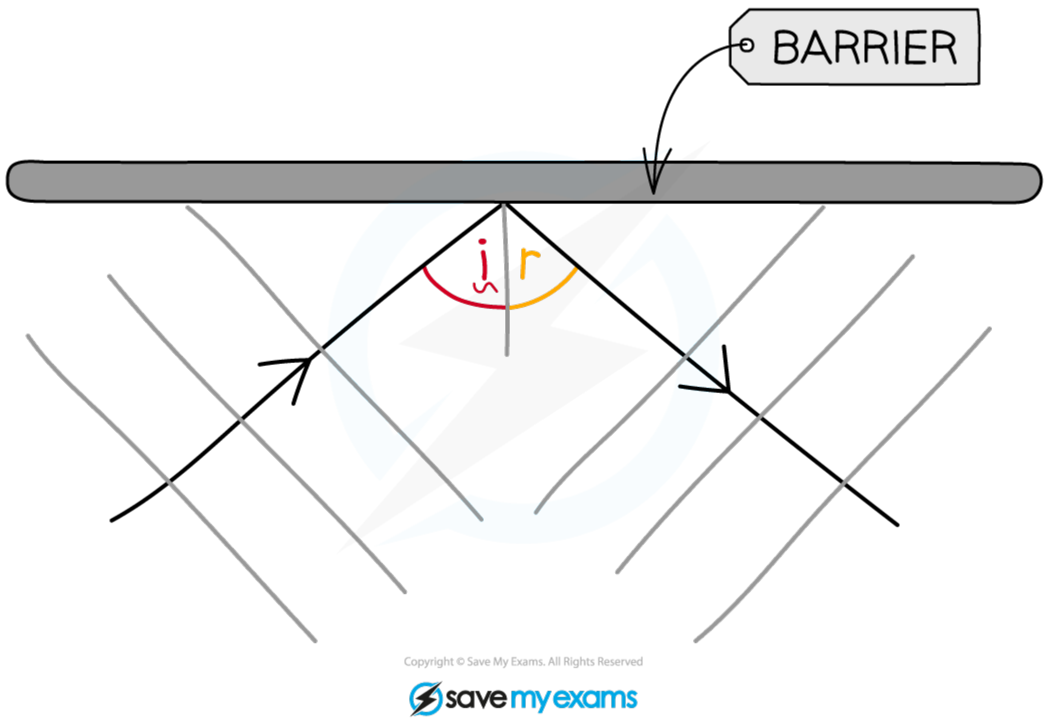
3.1.2 WAVE EFFECTS

Reflection

- When waves hit an object, such as a barrier, they can be reflected:



When waves reflect off a barrier, the angle of reflection, r, is equal to the angle of incidence, i

- When waves are reflection:

angle of incidence = angle of reflection

i = r

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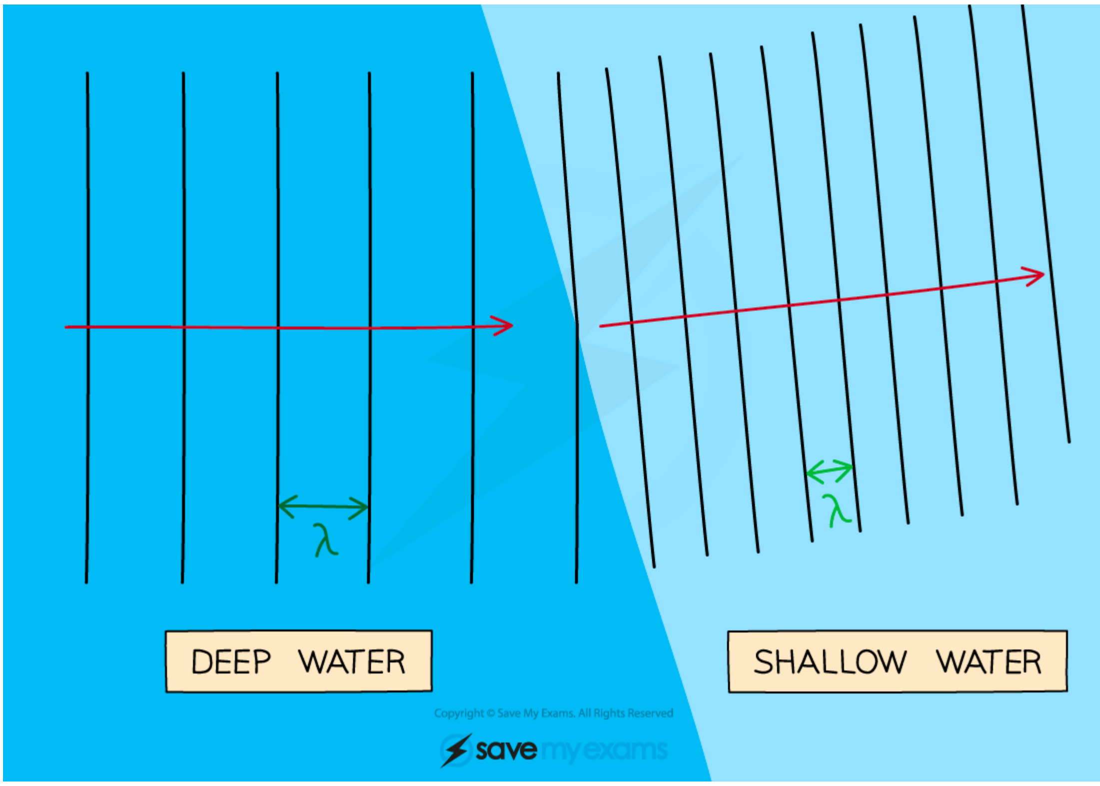
Refraction

- **When waves enter a different medium, their speed can change**
- **This effect is called refraction**, and it can have two other effects:
  - **The wavelength of the waves can increase or decrease**
  - **The waves can change direction**



When water waves travel from deep areas to shallow areas they slow down

- If the waves slow down the waves will bunch together, causing the wavelength to decrease. The waves will also start to travel closer to the normal
- If the waves speed up then they will spread out, causing the wavelength to increase. The waves will also turn slightly away from the normal

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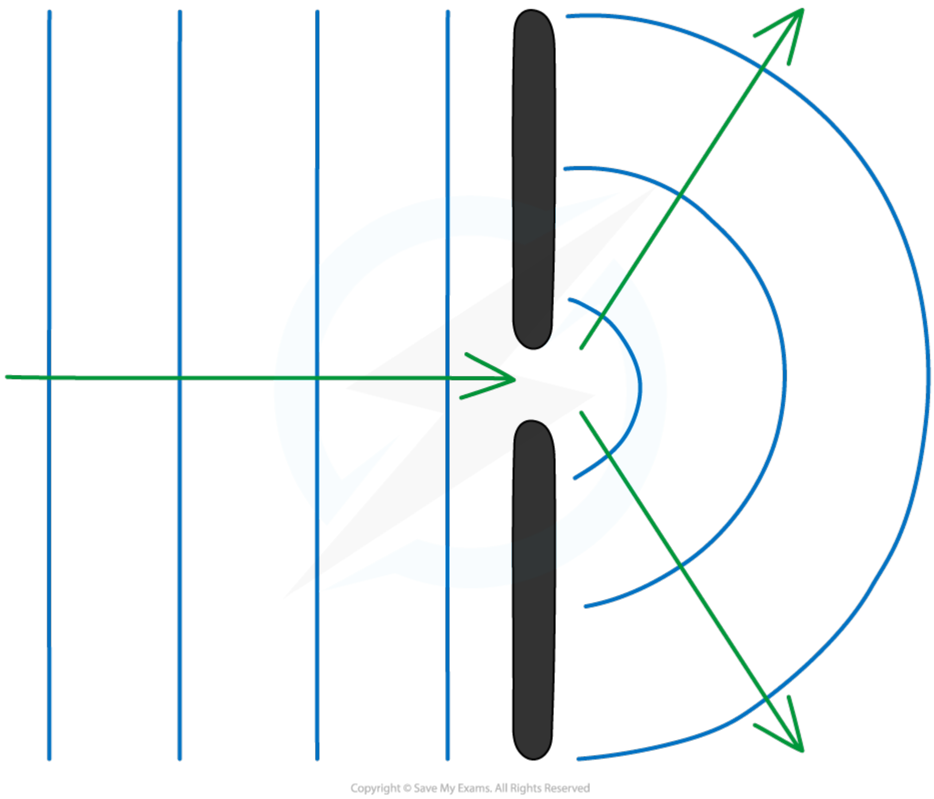
Diffraction

- When waves pass through a narrow gap, **the waves spread out**
- This effect is called diffraction



Diffraction: when a wave passes through a narrow gap, it spreads out

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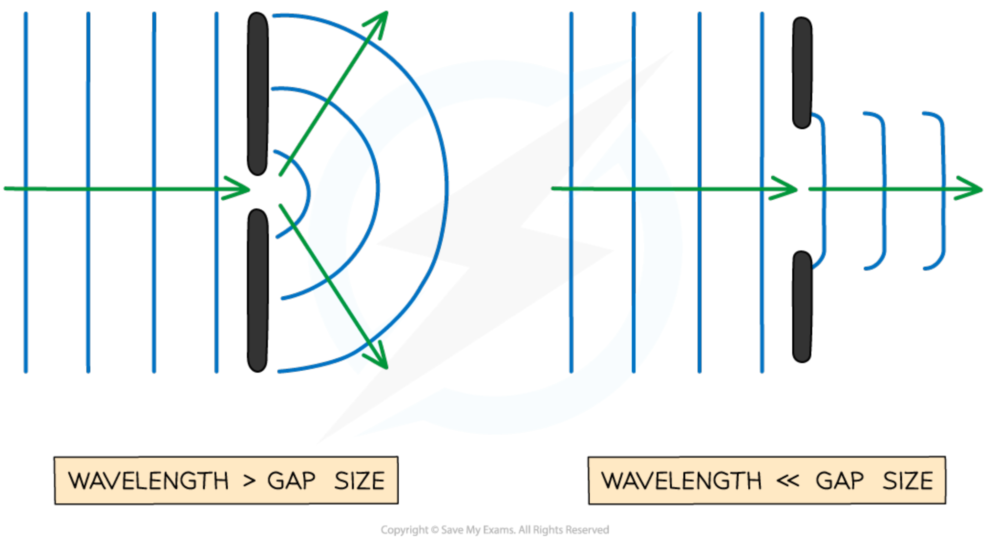
Factors Affecting Diffraction

- Diffraction, as shown above, only generally happens when the gap is smaller than the wavelength of the wave
- As the gap gets bigger, the effect gradually gets less pronounced until, in the case that the gap is very much larger than the wavelength, the waves no longer spread out at all



The size of the gap (compared to the wavelength) affects how much the waves spread out

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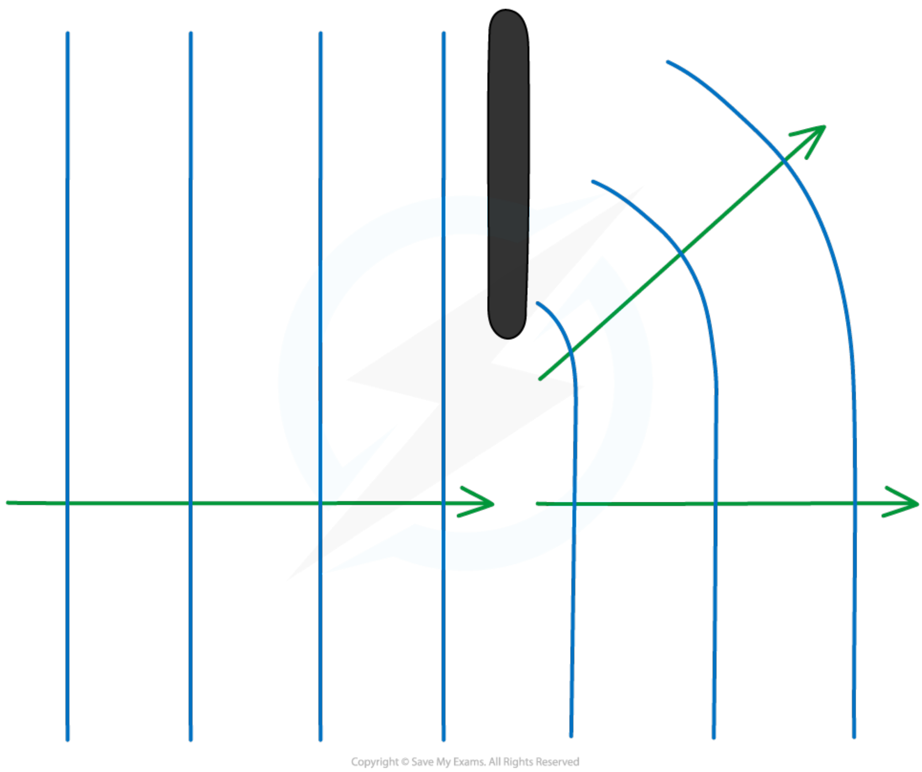
- Diffraction can also occur when waves pass an edge



When a wave goes past the edge of a barrier, the waves can curve around the edge

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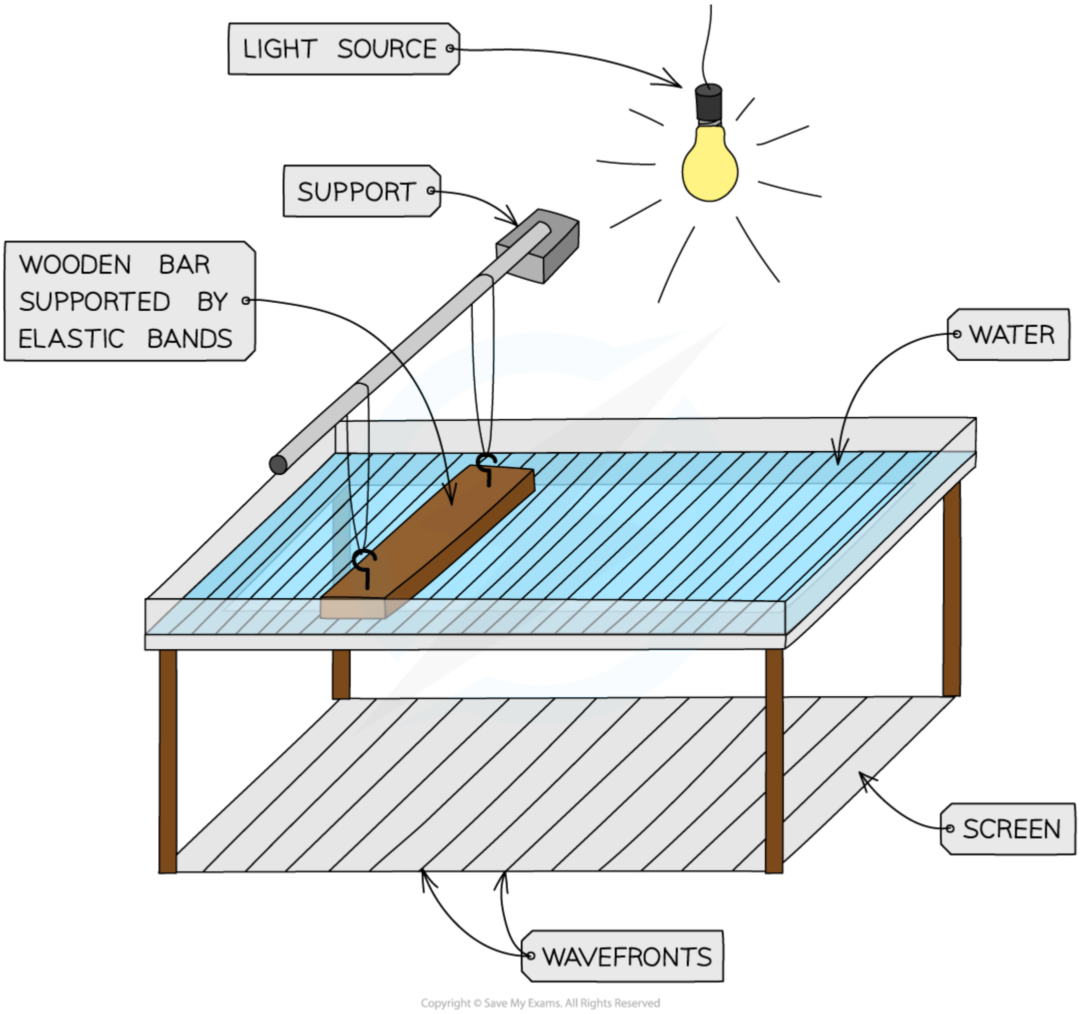
Demonstrating Wave Effects



The above wave effects may all be demonstrated using a ripple tank

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YOUR NOTES

Exam Tip

When drawing waves being reflected take care to:

- Make sure that the angle of incidence is equal to the angle of reflection
- Keep the wavelength of the waves the same

Similarly, when waves are diffracted **the wavelength remains constant.**

Refraction is the one wave effect where the wavelength changes.

Remember:

Refraction is the name given to the change in the speed of a wave when it passes from one medium to another. The change in direction is a consequence of this.

Exam Question: Easy

The following table shows some examples of waves

Which row correctly lists the nature of each of the wave types?

	sound waves	infrared waves	red light waves
A	transverse	longitudinal	transverse
B	longitudinal	transverse	transverse
C	longitudinal	longitudinal	transverse
D	transverse	transverse	longitudinal

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Exam Question: Hard

Sound waves travel at a speed of 1500 m/s through a substance. Their wavelength is 5.00 cm.

What is their frequency?

A 30 kHz

B 75 Hz

C 7.5 kHz

D 300 Hz

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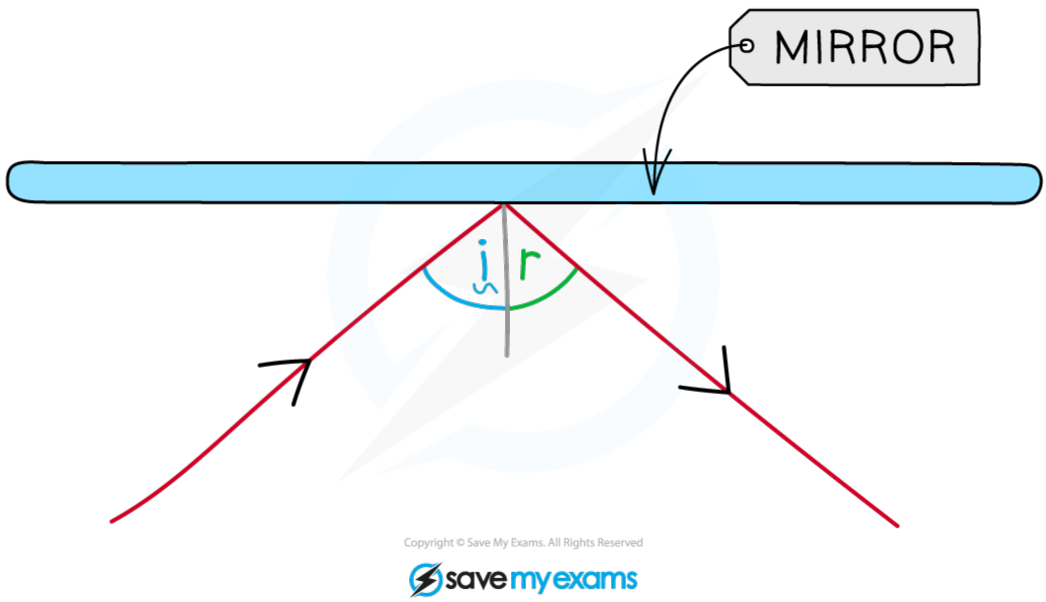
3.2 LIGHT

3.2.1 REFLECTION OF LIGHT

Incidence & Reflection

- Light is part of the electromagnetic spectrum – a family of **transverse waves**
- As with all wave, when light reflects:



Angle of incidence, i = angle of reflection, r

Mirrors

- When an object is placed in front of a mirror, an image of that object can be seen in the mirror
- The image:
    - Is the same size as the object
    - Is the same distance behind the mirror as the object is in front of it
    - Is directly in line with the object

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Virtual Image & Ray Diagram

- The formation of this image can be understood by drawing a ray diagram

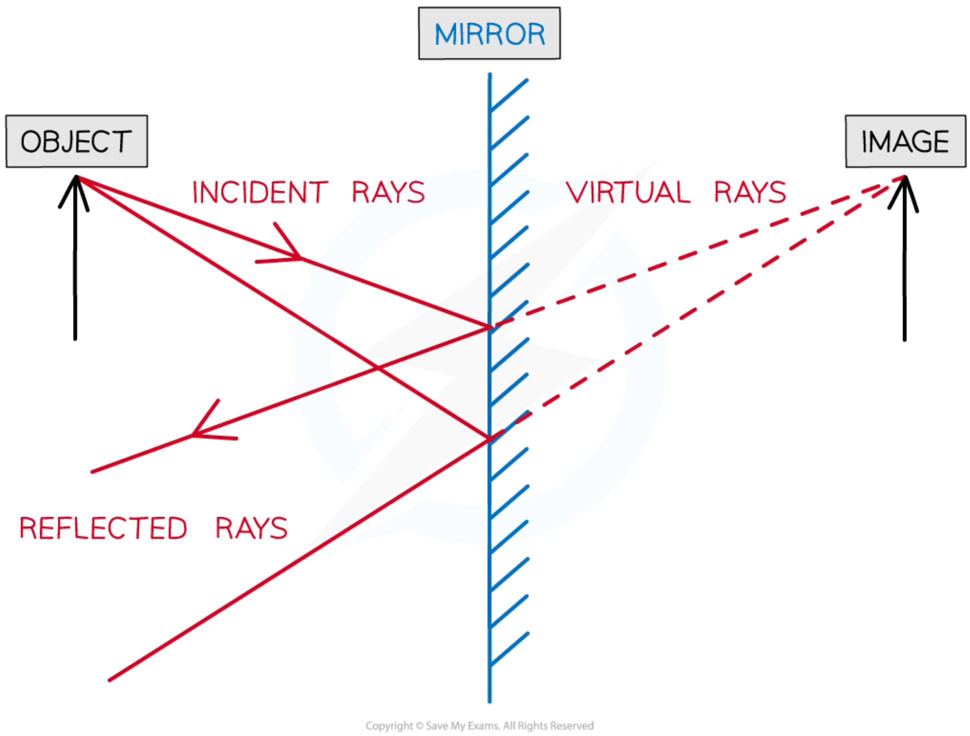

Diagram showing the formation of an image in a mirror by the reflection of light

- Light from the object hits the mirror, reflecting from it (*i*=*r*)
- To an observer, the reflected ray appears to have come from the right-hand side of the mirror
- The reflected ray can be traced back in this directions, forming a **virtual ray**

- This can be repeated for another ray travelling in a slightly different direction
- An image of the object will appear where these two virtual rays cross
- The type of image formed in the mirror is called a **virtual image**
- A virtual image is formed by the divergence of rays from the image, and cannot be projected onto a piece of paper (because the rays don't actually go through the image)

3. Properties of Waves, including Light & Sound

YOUR NOTES
⬇

Exam Tip

When drawing light waves being reflected **take care to get the angle about right.**

If they are slightly out it won't be a problem, but if there is an obvious difference between the angle of incidence and the angle of reflection then you will probably lose a mark.

3. Properties of Waves, including Light & Sound

YOUR NOTES

3.2.2 REFRACTION OF LIGHT

Refraction

- When light enters a glass block, it slows down, causing it to change direction
- When it leaves the block it speeds up again, changing direction once more

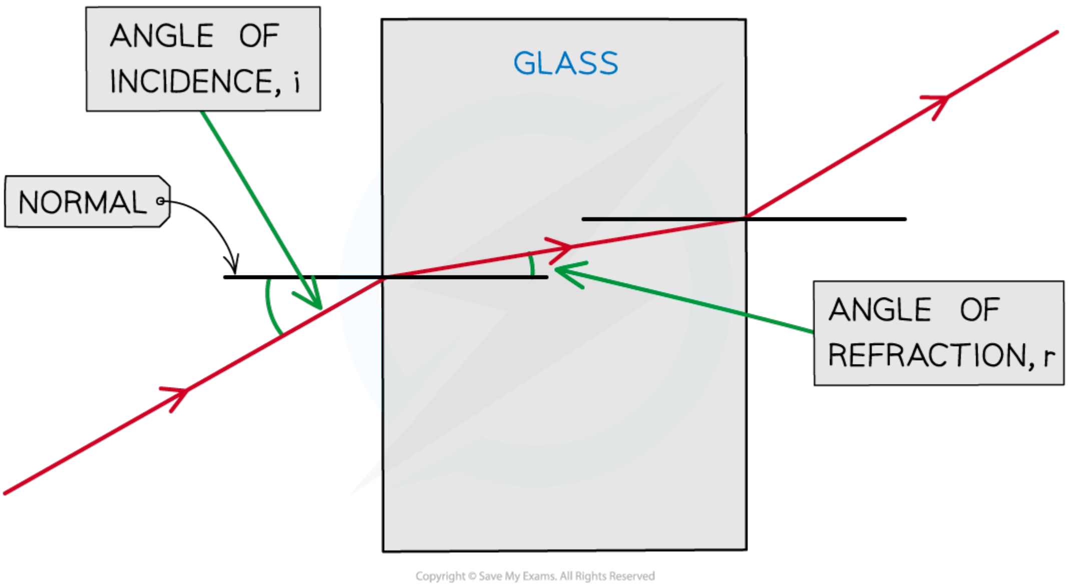

Diagram showing the refraction of light as it passes through a rectangular block

- As the light **enters** the block it bends **towards** the normal line (**Remember: Enters Towards**)
- When it **leaves** the block it bends **away** from the normal line (**Remember: Leaves Away**)

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Investigating Refraction

- In your examination you might be asked to write a method explaining how you might investigate the refraction of light through different shaped blocks

- As part of this method you should describe:
  - What equipment you need
  - How you will use the equipment
  - How you will trace the rays of light before, while and after they pass through the block

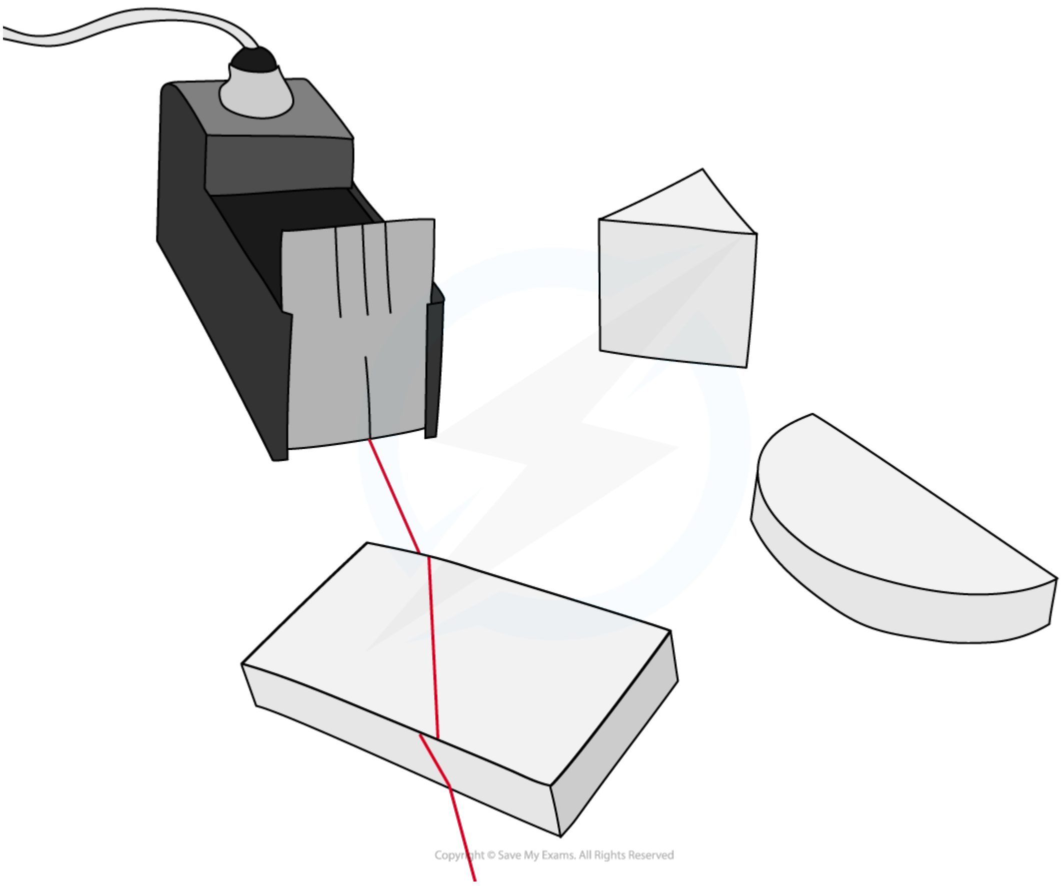

Diagram showing a ray box alongside three different shaped glass blocks

3. Properties of Waves, including Light & Sound

Method:

1. Place the glass block on a sheet of paper, and carefully draw around the block using a pencil
2. Take a ray box and carefully aim the box so that a single ray of light passes through the block
3. Using a pencil, mark some points along the path of the ray:
   Before it reaches the block;
   Where it hits the block;
   Where it leaves the block;
   After it has left the block
4. Now remove the block from the paper and, using a ruler and pencil, draw straight lines connecting points: *a and b; b and c; c and d.* The resulting line will show the path of the ray
5. Replace the block within its outline and repeat the above process for a ray striking the block at a different angle

Exam Tip

Key things to remember include:

-
    - Naming the apparatus that you need (remember the ray box)
    - Explaining how to trace the rays

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Snell's Law

- When light **enters a denser medium** (such as glass) it slows down and **bends towards the normal**

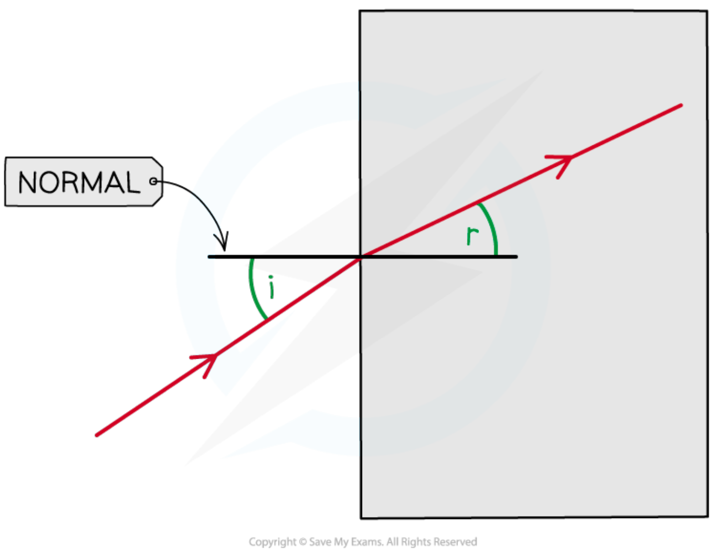


Diagram showing the angle of incidence, i, and the angle of refraction, r, of a ray of light entering a glass block

- Snell's law gives the relationship between the angle of incidence i, and the angle of refraction r:

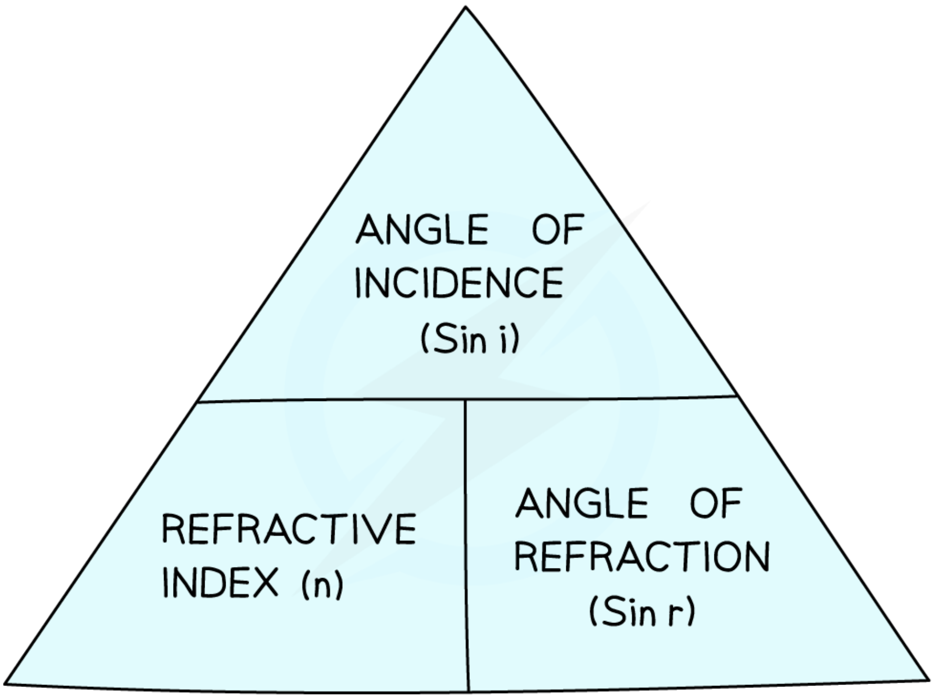
$$n = \frac{\sin i}{\sin r}$$

- Where ***n* is the refractive index of the material**

3. Properties of Waves, including Light & Sound

YOUR NOTES

- You can rearrange this equation with the help of the formula triangle:



Use the formula triangle to help you rearrange the equation

- The refractive index is related to the speed of light in the material (which is less than its speed in a vacuum):

$$\text{REFRACTIVE INDEX, } n = \frac{\text{SPEED OF LIGHT IN VACUUM}}{\text{SPEED OF LIGHT IN MATERIAL}}$$

- The refractive index is a number that is always bigger than 1 and is different for different materials (*n* is about 1.5 for glass)

3. Properties of Waves, including Light & Sound

YOUR NOTES

Exam Tip

Important: (*sin i / sin r)* is not the same as *(i/r)*. Incorrectly cancelling the *sin* terms is a common mistake.

When calculating the value of *i* or *r* start by calculating the value of *sin i* or *sin r.*

You can then use the **inverse sin** function (sin^{-1} on most calculators) to find the angle.

3. Properties of Waves, including Light & Sound

YOUR NOTES ⬇

3.2.3 TOTAL INTERNAL REFLECTION

How does Total Internal Reflection Occur?

- **When light is moving from a denser medium towards a less dense one**, most of the light is refracted, but a small amount of it can be **internally reflected**
- However, if the angle of the light is great enough then instead of being refracted, **ALL of the light is reflected**
- This is called **Total Internal reflection** and happens when the angle of the incident ray is greater than the critical angle for that material

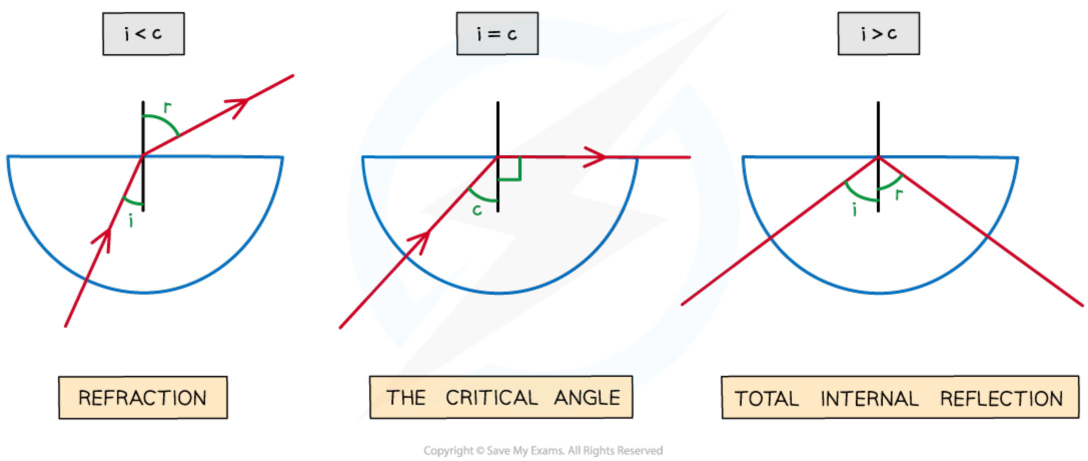


Diagram showing refraction, the critical angle and total internal reflection

- Two conditions are necessary for total internal reflection to occur:
  - The light must be going from a more dense medium towards a less dense one
- The angle of incidence must be greater than the **critical angle**

3. Properties of Waves, including Light & Sound

YOUR NOTES
⬇

Exam Tip

If asked to name the phenomena make sure you **give the whole name** – Total Internal Reflection.

Remember: Total Internal Reflection occurs when going from **more dense to less dense** and **ALL** of the light is reflected.

If asked to explain what is meant by the **critical angle**, you can draw the diagram above (showing the three semi-circular blocks).

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Refractive Index & Critical Angle Equation

- The **critical angle, c,** of a material is related to its **refractive index, *n***
- The relationship between the two quantities is given by the equation:

$$\sin c = \frac{1}{n}$$

This can also be written as:

$$n = \frac{1}{\sin c}$$

Exam Tip

When calculating the value of the critical angle using the above equation:

- First use the refractive index, *n*, to find *sin c*
- Then use the inverse sin function (sin^{-1}) to find the value of *i*

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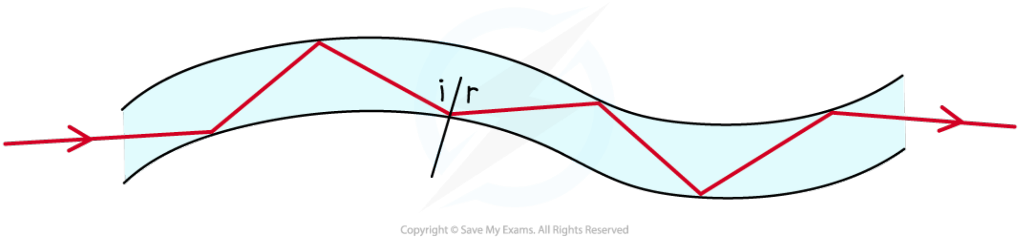
Optical Fibres

- Total internal reflection is also used to reflect light along **optical fibres**, allowing the high-speed transmission of data on the internet



Light travelling down an optical fibre is reflected each time it hits the edge of the fibre

- Additionally, optical fibres can be used in medicine in order to see within the human body

3. Properties of Waves, including Light & Sound

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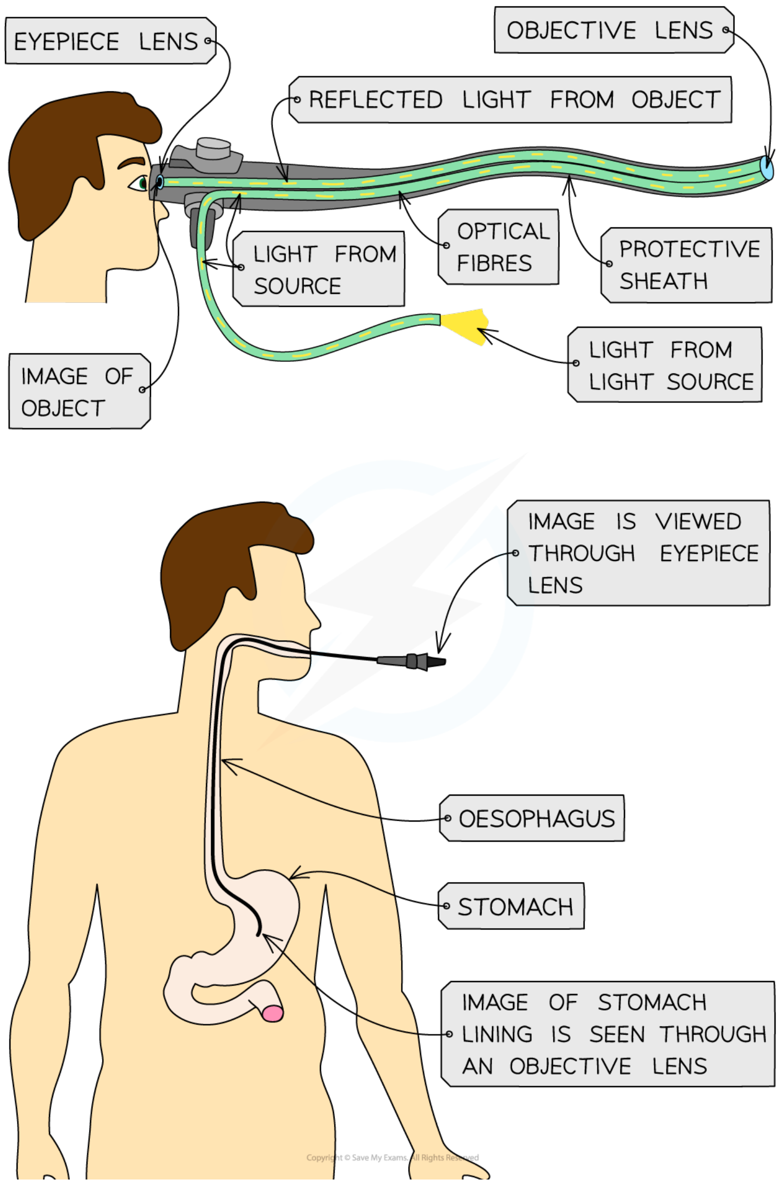


Diagram showing the application of total internal reflection in medicine (using an endoscope)

Exam Tip

When drawing light reflecting down an optical fibre, make sure that each time it reflects **the angle of reflection is equal to the angle of incidence.**

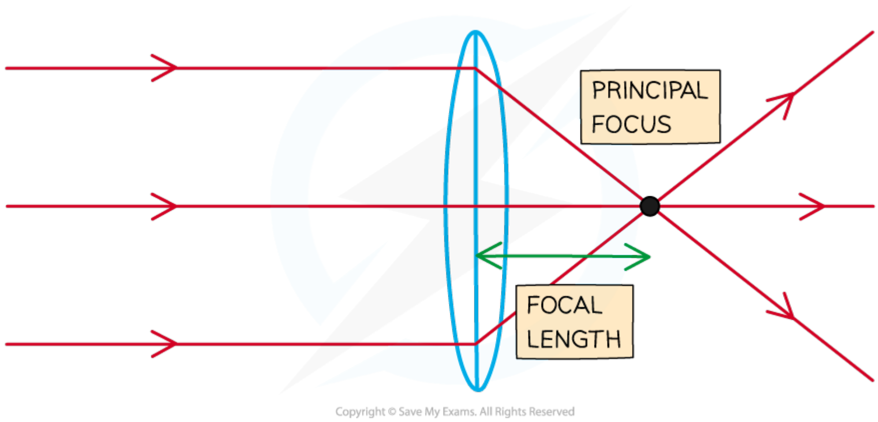
3. Properties of Waves, including Light & Sound

YOUR NOTES

3.2.4 THIN CONVERGING LENS

Converging Lenses

- When parallel rays of light (travelling parallel to the principal axis) pass through a lens, they are brought to a focus at a point known as the **principal focus**



A converging lens brings parallel rays of light to a focus

- The distance of the principal focus from the lens is called the **focal length**, and depends on how curved the lens is

3. Properties of Waves, including Light & Sound

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Forming a Real Image

- Lenses can be used to form images of objects placed in front of them
- The location (and nature) of the image can be found by drawing a ray diagram:

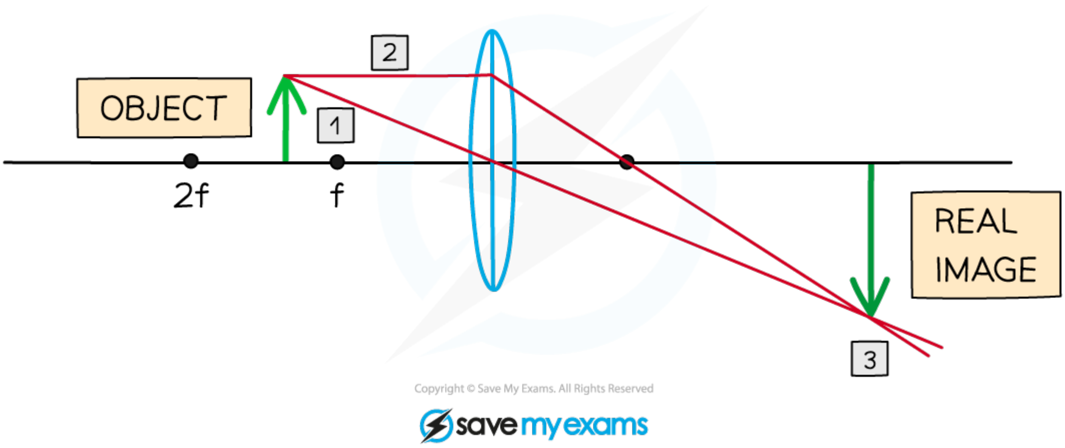

Diagram showing the formation of a real image by a lens

1. Start by drawing a ray going from the top of the object through the centre of the lens. This ray will continue to travel in a straight line
2. Next draw a ray going from the top of the object, travelling parallel to the axis to the lens. When this ray emerges from the lens it will travel directly towards the principal focus
3. The image is found at the point where the above two rays meet

- The above diagram shows the image that is formed when the object is placed at a distance between one focal length (f) and two focal lengths (2f) from the lens
- In this case, the image is:
    - **Real**
    - **Enlarged**
    - **Inverted**

3. Properties of Waves, including Light & Sound

YOUR NOTES
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- The following diagram shows what happens when the object is more distanced – further than twice the focal length (2f) from the lens:

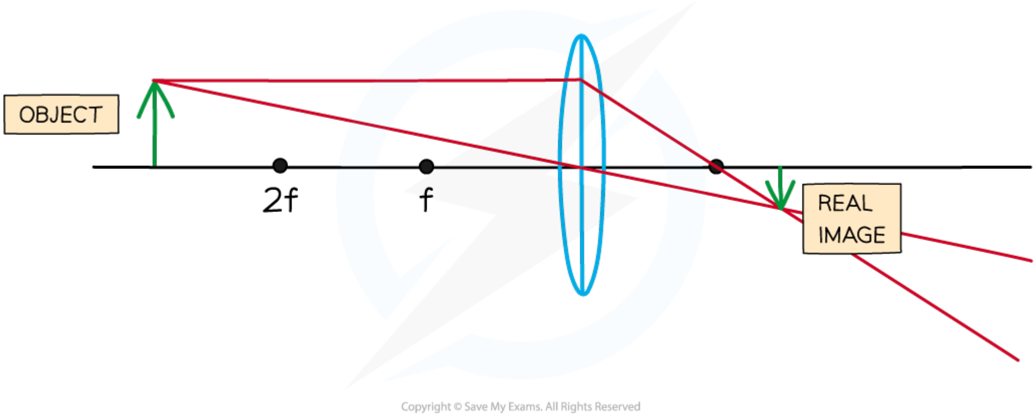

Diagram showing the formation of a real image by a lens with the object at distance

- In this case the image is:
  - **Real**
  - **Diminished (smaller)**
  - **Inverted**

- If the object is placed at exactly twice the focal length (2f) from the lens:

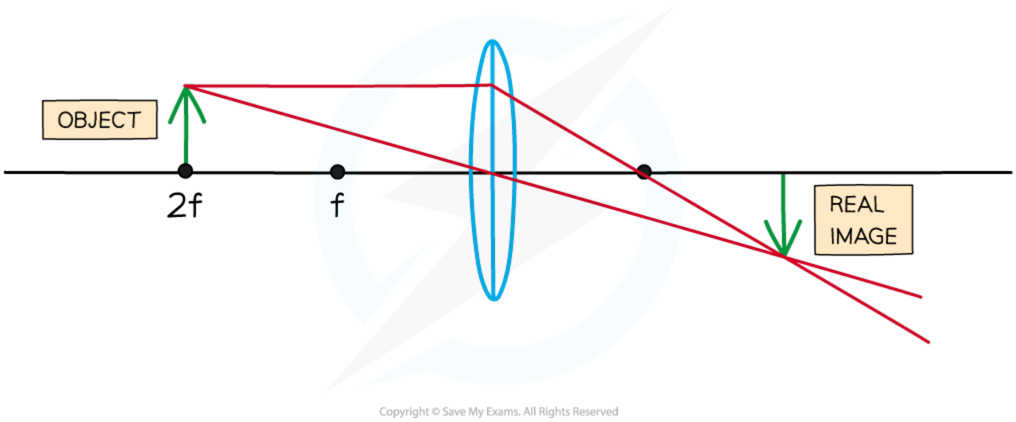

Diagram showing the formation of a real image with the object at 2f

3. Properties of Waves, including Light & Sound

YOUR NOTES
⬇

- In this case the image is:
  - **Real**
  - **Same size as the object**
  - **Inverted**

3. Properties of Waves, including Light & Sound

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Features of a Real Image

- A real image is one formed by the convergence of rays of light
- A real image can be projected onto a screen

3. Properties of Waves, including Light & Sound

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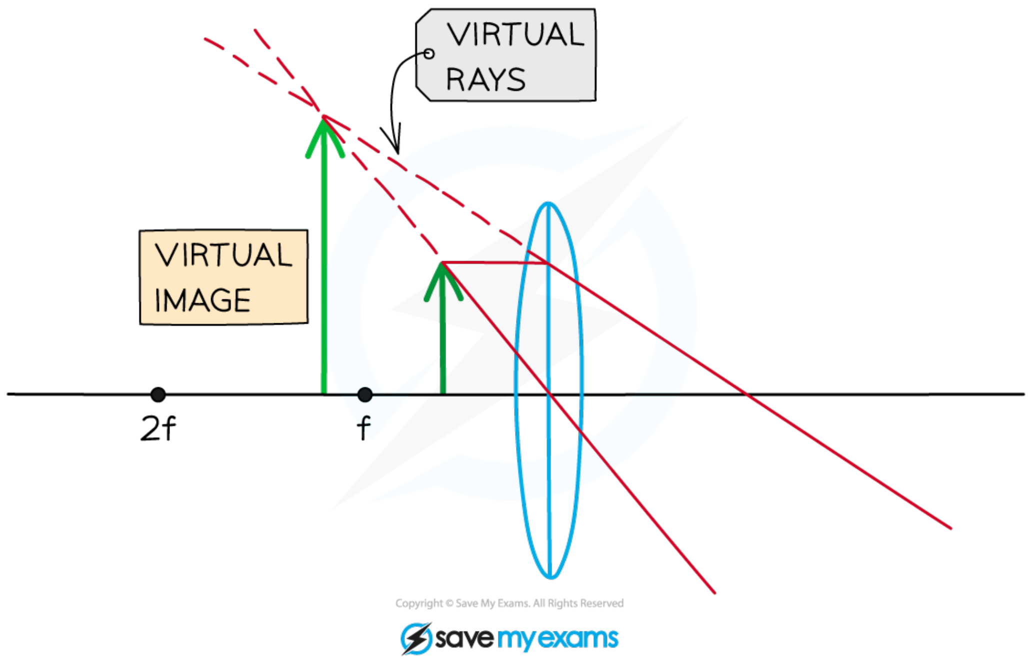
Magnifying Glasses

- If the object is placed closer to the lens than the focal length, the emerging rays diverge and a real image is no longer formed
- When viewed from the right-hand side of the lens, the emerging rays appear to come from a point on the left. This point can be found by extending the rays backwards (creating virtual rays)
- A virtual image will be seen at the point where these virtual rays cross



A virtual image is formed by the divergence of rays from a point

- In this case the image is:
  - **Virtual**
  - **Enlarged**
  - **Upright**
- Using a lens in this way allows it to be used as a **magnifying glass**
- When using a magnifying glass, the lens should always be held close to the object

3. Properties of Waves, including Light & Sound

YOUR NOTES
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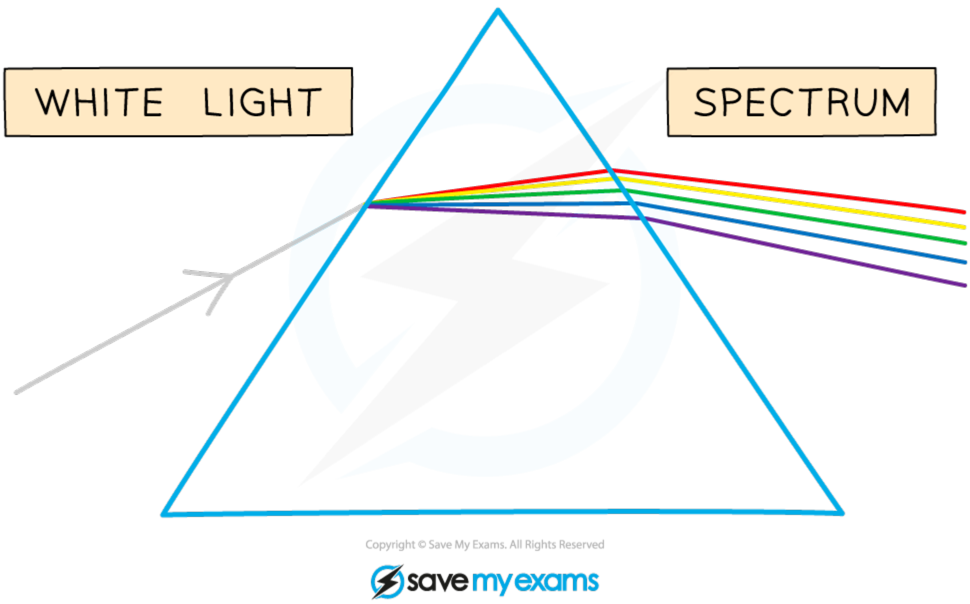
3.2.5 DISPERSION OF LIGHT

What is Dispersion of Light?

- When light enters a denser medium, such as glass, it slows down (refracts), which causes it to bend
- Different colours, however, slow down by different amounts, which causes them to bend by different amounts
- This effect is known as dispersion and can be used to separate white light into its individual colours



When white light is shone through a prism it is dispersed into its individual colours

- The seven colours of the spectrum are:

Red, Orange, Yellow, Green, Blue, Indigo, Violet

3. Properties of Waves, including Light & Sound

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- You can remember these colours either by remember the name:

`Roy G. Biv`

- Or by remembering the phrase:

Richard **O**f **Y**ork **G**ave **B**attle **I**n **V**ain

3. Properties of Waves, including Light & Sound

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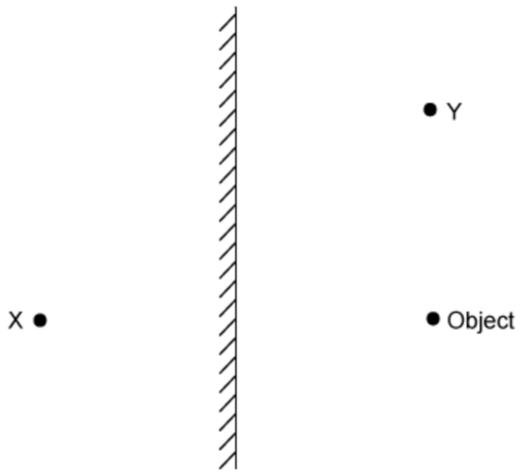
Light as a Wavelength

- Light is a transverse wave
- The different colours of light all have different wavelengths (and frequencies)
  - Red has the largest wavelength
  - Violet has the shortest wavelength
- Light of a single wavelength (a single colour) is known as **monochromatic**

Exam Question: Medium



An object is placed in front of a mirror. Where is the image formed, and is the image real or virtual?

	image location	image type
A	X	real
B	X	virtual
C	Y	real
D	Y	virtual

3. Properties of Waves, including Light & Sound

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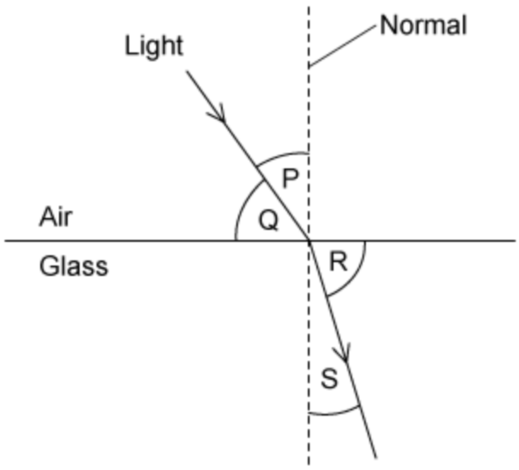
Exam Question: Hard

The diagram shows light passing from air into glass. A number of angles have been labelled on the diagram.



Which of the equations could be used to correctly calculate the refractive index, *n*, of the glass?

A $\frac{\sin P}{\sin S}$ **B** $\frac{\sin Q}{\sin R}$ **C** $\frac{\sin P}{\sin R}$ **D** $\frac{\sin Q}{\sin S}$

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3. Properties of Waves, including Light & Sound

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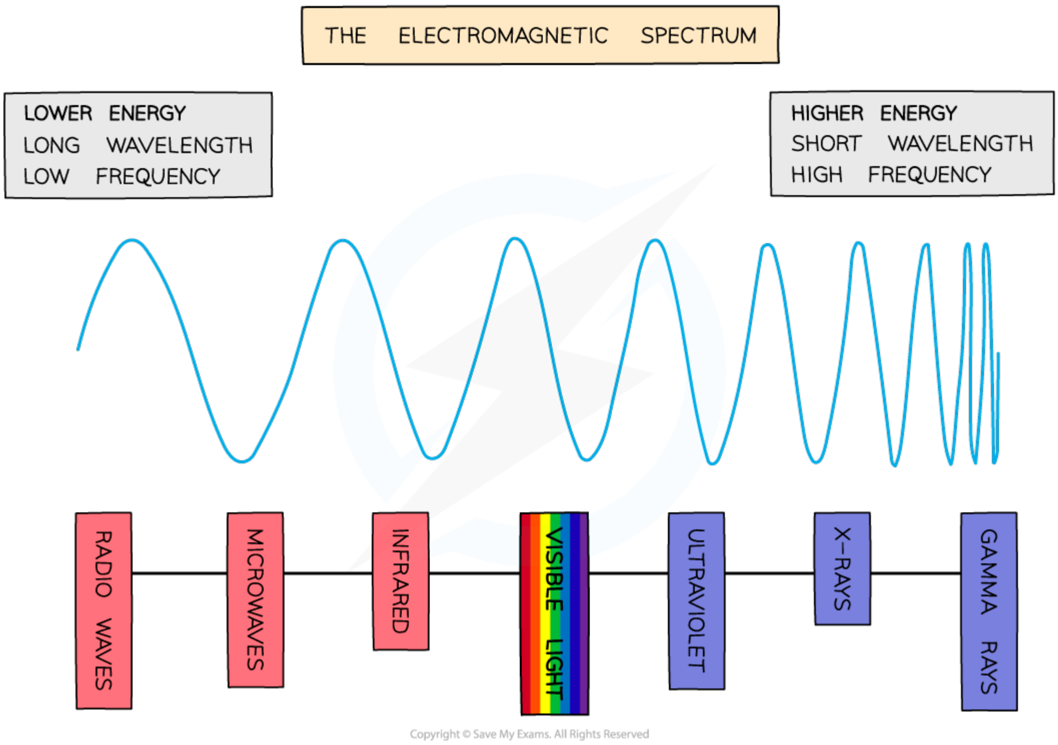
3.3 ELECTROMAGNETIC SPECTRUM

3.3.1 THE ELECTROMAGNETIC SPECTRUM

Parts & Properties of the Electromagnetic Spectrum

- Visible light, however, is just one small part of a much bigger spectrum: the electromagnetic spectrum
- The different parts of the spectrum have different names (and some different properties)
- These parts are shown in order below, going from the longest wavelength (and lowest frequency) to the shortest wavelength (and highest frequency)



Visible light is just one small part of a much bigger spectrum: The electromagnetic spectrum

- All electromagnetic waves share several properties:
  - **They are all transverse**
  - **They can all travel through a vacuum**
  - **They all travel at the same speed in a vacuum**

3. Properties of Waves, including Light & Sound

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The Speed of Electromagnetic Waves

- The speed of light, in a vacuum, is approximately ***3 x 10^8 m/s***
- The speed of light in air is approximately the same

Uses of Electromagnetic Waves

- Electromagnetic waves have a large number of uses. The main ones are summarised in the table below

WAVE	USE
RADIO	• COMMUNICATION (RADIO AND TV)
MICROWAVE	• HEATING FOOD • COMMUNICATION (WIFI, MOBILE PHONES, SATELLITES)
INFRARED	• REMOTE CONTROLS • FIBRE OPTIC COMMUNICATION • THERMAL IMAGING (MEDICINE AND INDUSTRY) • NIGHT VISION • HEATING OR COOKING THINGS • MOTION SENSORS (FOR SECURITY ALARMS)
VISIBLE LIGHT	• SEEING AND TAKING PHOTOGRAPHS/VIDEOS
ULTRAVIOLET	• SECURITY MARKING (FLUORESCENCE) • FLUORESCENT BULBS • GETTING A SUNTAN.
X-RAYS	• X-RAY IMAGES (MEDICINE, AIRPORT SECURITY AND INDUSTRY)
GAMMA RAYS	• STERILISING MEDICAL INSTRUMENTS TREATING CANCER

3. Properties of Waves, including Light & Sound

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- **Radio waves and microwaves**
  - These two parts of the spectrum share a lot of similarities and uses. Their main uses concern wireless communication – in fact many things that people often assume use radio waves actually use microwaves (e.g. WiFi, radar, mobile phones, satellite communications…)
  - At very high intensity, microwaves can also be used to heat things: This is what happens in a microwave oven
- **Infrared**
  - Infrared is emitted by warm objects and can be detected using special cameras (thermal imaging cameras). These can be used in industry, in research and also in medicine
  - Many security cameras are capable of seeing slightly into the infrared part of the spectrum and this can be used to allow them to see in the dark: Infrared lights are used to illuminate an area without being seen, which is then detected using the camera
  - Remote controls also have small infrared LEDs that can send invisible signals to an infrared receiver on a device such as a TV
  - Infrared travels down fibre optic cables more efficiently than visible light, and so most fibre optic communication systems use infrared
- **Ultraviolet**
  - Ultraviolet is responsible for giving you a suntan, which is your body's way of protecting itself against the ultraviolet
  - When certain substances are exposed to ultraviolet, they absorb it and re-emit it as visible light (making them glow). This process is known as fluorescence
  - Fluorescence can be used to secretly mark things using special ink – in fact most bank notes have invisible fluorescent markings on them
  - Fluorescent light bulbs also use this principle to emit visible light
- **X-rays**
  - The most obvious use of x-rays is in medicine. X-rays are able to pass through most body tissues, but are absorbed by the denser parts of the body, such as bones. When exposed to x-rays, bones create a shadow which can be seen using a special x-ray detector or using photographic film
- **Gamma rays**
  - Gamma rays are very dangerous and can be used to kill cells and living tissue
    If the gamma rays are carefully aimed at cancerous tissue they can be very effective at killing it
    Gamma rays can also be used to sterilise things by killing off the bacteria

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Dangers

- Electromagnetic Waves can have some harmful side effects. In particular:

Microwaves

- High levels of microwaves can cause heating of internal organs. (Although there is no evidence that the levels emitted by mobile phones or WiFi devices cause any harm)

X-Rays

- X-rays, Gamma rays and (to a lesser extent) ultra-violet are all ionising. This means that they can cause harm to living tissues: killing cells or possibly mutating them or causing cancer
- Whilst the levels used in most medical x-rays pose a minimum risk, hospitals are careful to minimise the amount of x-ray exposure that individuals (including hospital staff) receive

3. Properties of Waves, including Light & Sound

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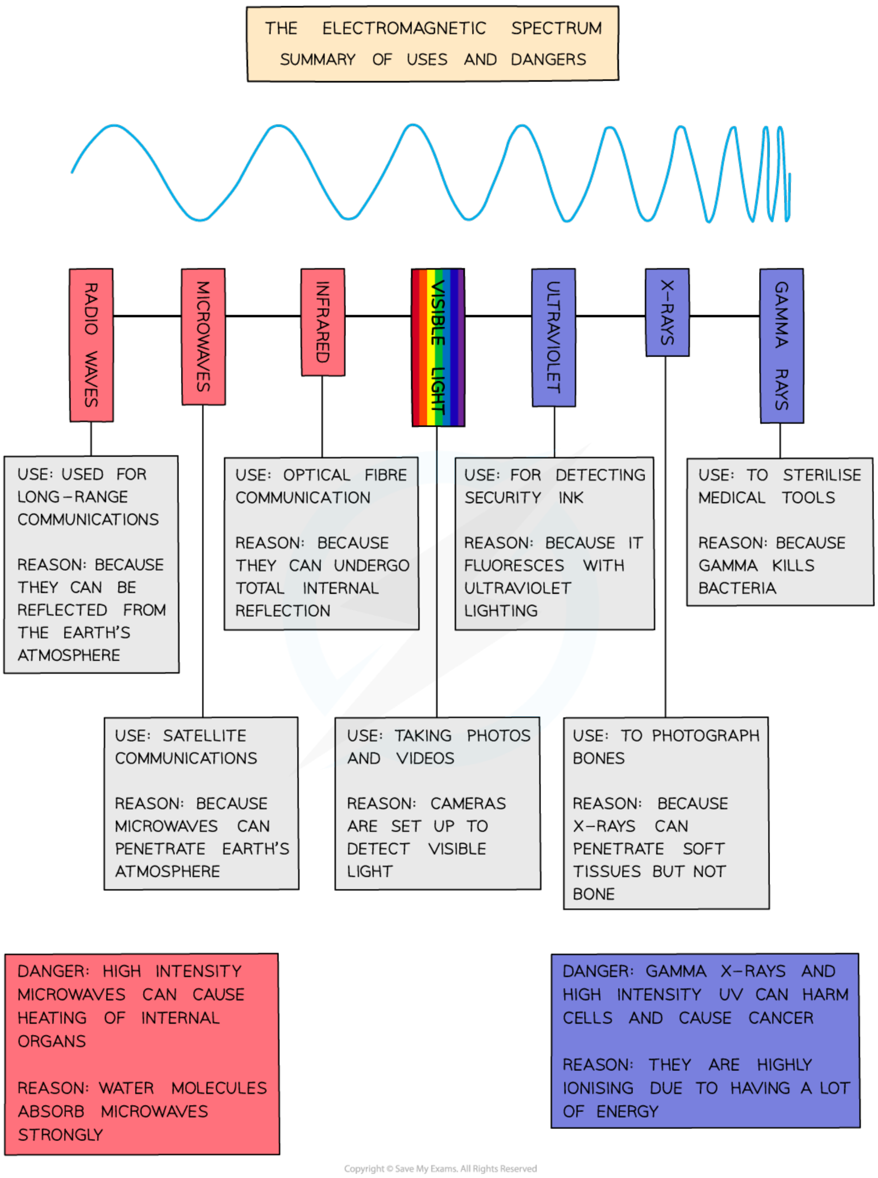

Uses and dangers of the electromagnetic spectrum

3. Properties of Waves, including Light & Sound

YOUR NOTES

Exam Question: Easy

Which row of the table shows the correct wave type for sound waves, gamma rays and blue light waves?

	sound waves	gamma rays	blue light waves
A	transverse	transverse	transverse
B	transverse	longitudinal	transverse
C	longitudinal	transverse	transverse
D	longitudinal	longitudinal	transverse

Exam Question: Medium

Visible, red light has a wavelength of around 700 x 10^{-7} m.

Two other types of electromagnetic radiation, X and Y, have different wavelengths to the visible, red light.

Wavelength of X = 400 x 10^{-7} m
Wavelength of Y = 3.0 x 10^{-2} m

Which types of radiation could X and Y be?

	X	Y
A	visible blue light	microwaves
B	x-rays	ultraviolet
C	infrared	radio waves
D	microwaves	ultraviolet

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3. Properties of Waves, including Light & Sound

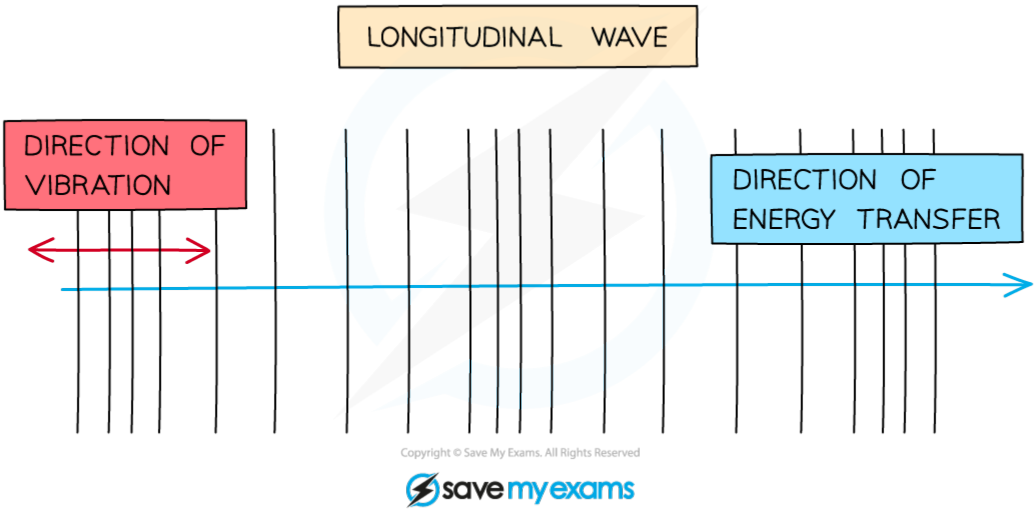
YOUR NOTES

3.4 SOUND

3.4.1 SOUND & ULTRASOUND

Sound

- Sound waves consist of vibrating molecules. They are a type of **longitudinal wave**



Sound waves are longitudinal: the molecules vibrate in the same direction as the energy transfer

- **Sound waves require a medium to travel through**
  If there are no molecules (e.g. in a vacuum) then the sound can't travel
- The **Loudness** of a sound is related to the wave's **amplitude**
  (Greater amplitude = louder sound)
- The **Pitch** of a sound is related to the **frequency**
  (Greater frequency = higher pitch)
- As with all waves, sound waves can be reflected
  The reflection of a sound wave is called an echo

3. Properties of Waves, including Light & Sound

YOUR NOTES

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Compression & Rarefaction

- Longitudinal waves consist of **compression and rarefactions**:
  - A compression is a place where the molecules are bunched together
  - A rarefaction is a place where the molecules are spread out

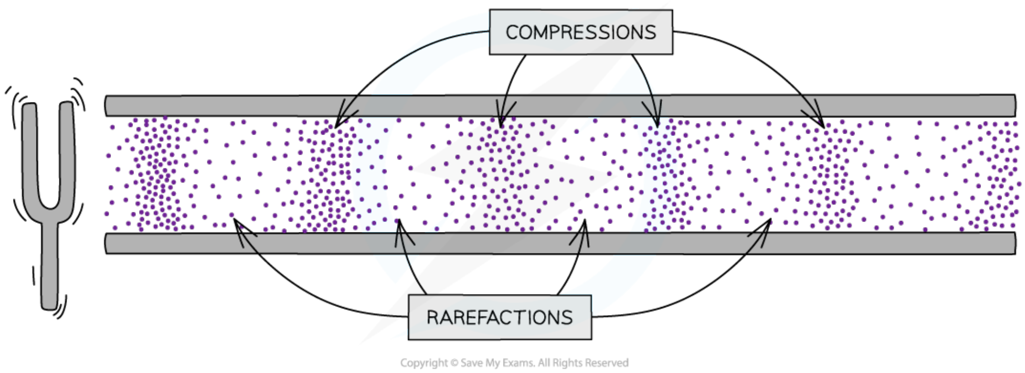

Diagram showing the compressions and rarefactions of longitudinal waves

3. Properties of Waves, including Light & Sound

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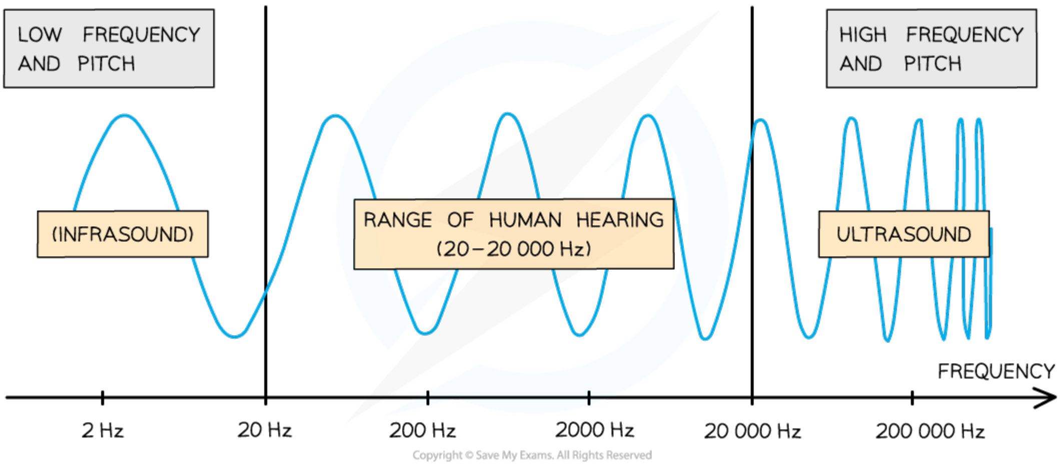
Ultrasound

- Humans can hear sounds between about 20 Hz and 20 000 Hz in frequency (although this range decreases with age)



Humans can hear sounds between 20 and 20 000 Hz

- **Ultrasound** is the name given to sound waves with a frequency greater than 20 000 Hz

3. Properties of Waves, including Light & Sound

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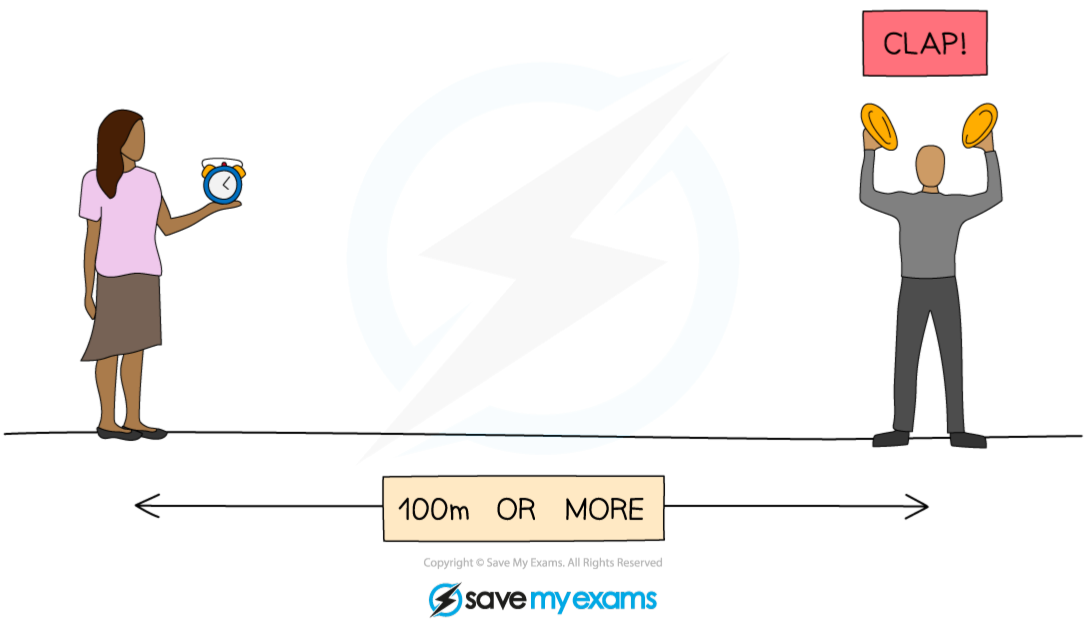
3.4.2 THE SPEED OF SOUND

Experiments to Determine the Speed of Sound

- In your IGCSE exam, you might be asked to describe a method of measuring the speed of sound
- When giving your method, try and include the following things:
  - List all of the apparatus that you will need
  - Choose a suitable (realistic) distance over which you will measure the sound
  - Describe how you will measure this distance
  - Explain how you will produce a loud enough sound
  - Explain how you will time the sound (and how the timer will be started and stopped)
  - Explain how you will calculate the speed (give an equation)
  - State that you will then repeat the experiment several times and take an average
- Three methods for carrying out this experiment are given below:

Method 1



Measuring the speed of sound directly between two points

3. Properties of Waves, including Light & Sound

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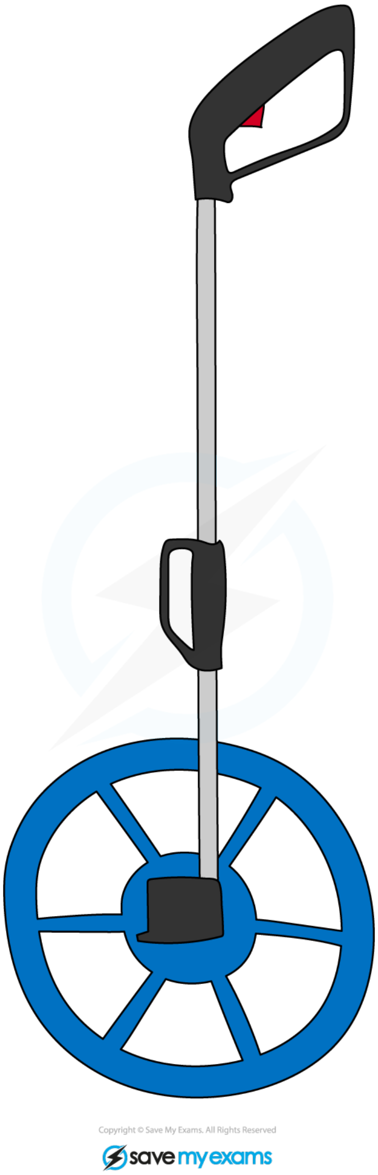
1. Two people stand a distance of around 100m apart
2. The distance between them is measured using a trundle wheel
3. One of the people has two wooden blocks, which he bangs together above his head
4. The second person has a stopwatch which he starts when he sees the first person banging the blocks together and stops when he hears the sound
5. This is then repeated several times and an average value is taken for the time
6. The speed of sound can then be calculated using the equation:

$$\text{SPEED OF SOUND} = \frac{\text{DISTANCE TRAVELED BY SOUND}}{\text{TIME TAKEN}}$$

3. Properties of Waves, including Light & Sound

YOUR NOTES



A trundle wheel can be used to measure large distances

3. Properties of Waves, including Light & Sound

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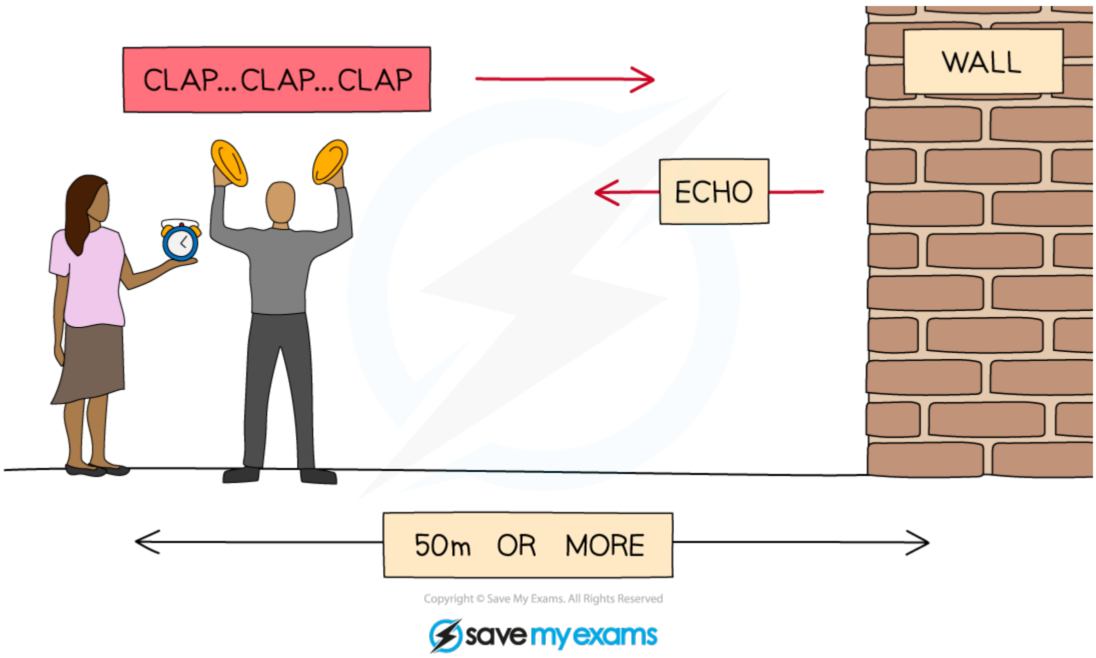
Method 2



Measuring the speed of sound using echoes

1. A person stands about 50m away from a wall (or cliff). This distance is measured using a trundle wheel
2. The person claps two wooden blocks together and listens for the echo
3. The person then starts to clap the blocks together repeatedly, in rhythm with the echoes
4. A second person has a stopwatch and starts timing when he hears one of the claps and stops timing 20 claps later
5. The process is then repeated and an average time calculated
6. The distance travelled by the sound between each clap and echo will be (2 x 50) m
7. The total distance travelled by sound during the 20 claps will be (20 x 2 x 50) m
8. The speed of sound can be calculated from this distance and the time using the equation:

$$\text{SPEED OF SOUND} = \frac{\text{DISTANCE TRAVELED BY SOUND}}{\text{TIME TAKEN}}$$

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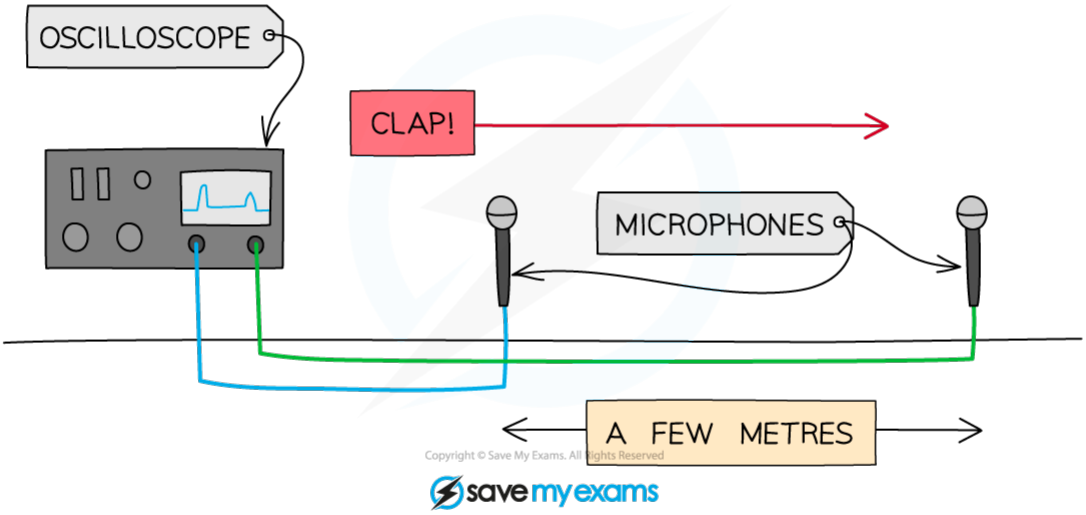
Method 3



Measuring the speed of sound using an oscilloscope

1. Two microphones are connected to an oscilloscope and placed about 5 m apart (This distance can be measured using a tape measure)
2. The oscilloscope is set up so that it triggers when the first microphone detects a sound, and the time base is adjusted so that the sound arriving at both microphones can be seen on the screen
3. Two wooden blocks are used to make a large clap next to the first microphone
4. The oscilloscope is then used to determine the time at which the clap reaches each microphone, and the time difference between them
5. This is repeated several times and an average time difference calculated
6. The speed can then be calculated using the equation:

$$\text{SPEED OF SOUND} = \frac{\text{DISTANCE TRAVELED BY SOUND}}{\text{TIME TAKEN}}$$

3. Properties of Waves, including Light & Sound

YOUR NOTES
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Exam Tip

Method 3 is the most accurate method (because the timing is done automatically) whilst method 1 is the least accurate (because the time interval is very short).

Whilst this may not be too important when giving a method, you should be able to explain why each method is accurate or inaccurate, and suggest ways of making them better (use bigger distances).

3. Properties of Waves, including Light & Sound

YOUR NOTES

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Speed of Sound by Medium

- Sound travels at different speeds in different mediums:
  - It travels fastest in solids
  - Slowest in gases

MEDIUM	TYPICAL SPEED
GAS	≈ 350 m/s
LIQUID	≈ 1500 m/s
SOLID	≈ 5000 m/s

Exam Question: Easy

Sound wave W has amplitude, *A*, and frequency, *f*.

Sound wave X is louder and lower in pitch than sound wave W.

What can be said about the amplitude and frequency of sound wave X?

	amplitude	frequency
A	higher than *A*	higher than *f*
B	higher than *A*	lower than *f*
C	lower than *A*	higher than *f*
D	lower than *A*	lower than *f*

3. Properties of Waves, including Light & Sound

YOUR NOTES

Exam Question: Hard

A fishing boat uses sonar to locate a shoal of fish. The sonar system sends a pulse of sound towards the shoal. When it hits the shoal, the sound wave is reflected and picked up by a detector underneath the ship.

The speed of sound in water is 1500 m/s.

The pulse of sound waves is received 0.48 s after it is emitted.

How far from the boat is the shoal of fish?

A 1563 m

B 3125 m

C 720 m

D 360 m

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